LONG ISLAND SOUND
DREDGE MATERIAL CONTAINMENT STUDY
PROTOTYPE REPORT
GEOTECHNICAL ENGINEERING BRANCH

US Army Corps of Engineers
New England Division
Engineering Division
Geotechnical Engineering Branch
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1. Regional Topography. The coastal area of Connecticut lies within the Seaboard Lowland section of the New England physiographic province. The lowland is generally characterized by a seaward sloping area that is roughly planar. The lowland in Connecticut extends inland up to 20 miles and usually lies under elevation 500 feet NGVD.[1]

The relatively low elevation of the seaboard lowland section in Connecticut is primarily not a function of weak rock, as the underlying igneous and metamorphic rocks are very competent. The present-day topographic features are caused by erosion of the pre-existing features and subsequent deposition resulting from glaciation. Relative sea level rise has slightly modified the topography along coastal areas.

2. Regional Geology. The lowland area of Connecticut between the cities of Guilford and Mystic is underlain by early to mid-Paleozoic igneous and metamorphic rocks. The igneous rocks consist primarily of granite, with smaller occurrences of tonalite and quartz monzonite. Pegmatite bodies are also prominent. The metamorphic rocks consist of gneiss, granite gneiss, and lesser amounts of amphibolite and schist.

Bedrock in the area is covered primarily by glacial till and glacially-deposited, roughly-stratified sand and gravel deposits. In the areas along the coast, the glacial deposits are overlain by a recent depositional sequence of lagoonal silt, peat and organic silt, and beach sand and gravel. Recent alluvial deposits of sand, silt, and gravel are found along river valleys. Extensive tracts of artificial fill are found throughout the area.

3. Seismicity. The lowland area of Connecticut is located in Zone 1 of the seismic zone map of the United States. This is a modification of the seismic risk map developed by the Environmental Science Administration and the Coast and Geodetic Survey and it is contained in Engineering Regulation 1110-2-1806 dated 30 April 1977. In accordance with this directive, a coefficient of 0.025 g is recommended for use in any evaluation of seismic stability of structures in final design.

[1]National Geodetic Vertical Datum (NGVD) is the mean sea level of 1929.

Detailed remote sensing and fault compilation did not reveal the presence of a major or capable fault within Connecticut or Rhode Island. Since 1568, 85 earthquakes have occurred in these two states. With respect to Clinton Harbor site, the nearest event with an epicenter based on historical data occurred approximately four miles from the site in 1948 with an intensity of II MM (Modified Mercalli), and the nearest event with an epicenter based on instrumental data occurred approximately 20 miles from the site in 1940 with an intensity of IV MM. With respect to the Black Ledge site, the nearest event with an epicenter based on historical data occurred approximately four miles from the site in 1827 with an intensity of IV MM, and the nearest event with an epicenter based on instrumental data occurred approximately 13 miles from the site in 1976 with an intensity of II MM.

4. Foundation Investigations. A detailed field reconnaissance of the sites was performed in June 1981 in order to describe and photograph existing conditions.

From November 1981 through January 1982, a preliminary subsurface exploration program consisting of machine probings and borings, was performed in order to define foundation conditions. A total of 11 probes and 3 borings were performed at Clinton Harbor Site and 22 probes and 5 borings were performed at the Black Ledge Site. Locations and depths of the explorations are shown on Plates 3 and 4 "Plan of Explorations and Geologic Profile", for both the Clinton Harbor and Black Ledge Sites. The graphic logs for the explorations at Clinton Harbor and Black Ledge are shown on Plates 5 and 7 respectively.

Overburden samples recovered from the exploration program were tested at the New England Division Materials and Water Quality Laboratory for the following: gradation, both by sieve and hydrometer; Atterberg Limits; organic contents; water content; and specific gravity. See Plates 1 and 2, Soil Test Results, for overburden test results for each site. The bedrock samples from Black Ledge were tested for specific gravity, absorption, and unconfined compressive strength.

5. Site Geology.

a. Clinton Harbor.

(1) Topography. The topography of the Clinton area is primarily glacially controlled. The area is generally flat, with the only relief being provided by till hills and end moraine. Maximum elevation in the area is approximately 15 feet NGVD. The offshore area is generally flat, with boulders providing some relief. Minimum offshore elevation at the site is approximately -8 feet NGVD.

(2) Surficial Geology. In general, Pleistocene-age, glacial deposits are dominant in the low-lying coastal areas. Overburden cover in the area appears to average 50 feet in thickness. The distribution of surficial materials is shown on Plate 6.

Glacial till in the area is a compact, non-sorted mixture of clay, silt, sand, gravel, cobbles, and boulders deposited by glacial ice. The till is found overlying bedrock and is exposed at the higher elevations of Hammonasset State Park. End moraine is found along Hammonasset Point and it projects through West Rock and Wheeler Rock across Clinton Harbor to Hammock Point. The end moraine in the area consists of northeast-southwest trending ridges and elongate mounds of till and stratified drift with local concentrations of large boulders.

Ice-contact stratified drift in the area is a somewhat deformed mixture of sand, gravel, silt, and clay that is poorly sorted with abrupt changes in grain size. These sediments were deposited in streams and temporary lakes in close relation to melting glacier ice. The ice-contact stratified drift deposits grade into glacial outwash deposits. These sediments consist primarily of sand and gravel showing cut-and-fill stratification. The stratified glacial deposits generally overlie till, although they overlie bedrock in areas where till is absent. These deposits tend to be found in valleys and flatter areas. Extensive area of outwash deposits are found throughout Clinton and Hammonasset State Park.

In addition to glacially-derived overburden, there is a relatively large sequence of post-glacial deposits. Lagoonal or estuarine deposits generally overlie the glacial deposits. They consist primarily of silt and organic silt with some shells and shell fragments. Swamp and marsh deposits, which overlie the lagoonal deposits, are the dominant surficial sediments in the Clinton-Hammonasset State Park area. These deposits consist of organic silt and clay with sand and peat fibers.

Lining the coast along Hammonasset Beach and Clinton Harbor to Cedar Island, and overlying the swamp deposits, is a sequence of beach sand and gravel and windblown sand. Extensive areas of land in Hammonasset State Park and along the coast in Clinton and Harborview have been filled. The fill is variable in composition from site to site but, in general, coarse sand and gravel are common fill materials.

Based on the borings and probes performed at Clinton Harbor, the recent sand and swamp sequence over most of the area is at least 40 feet thick. No glacial deposits were recovered from the boring samples; however, the refusals encountered in Boring B and Probe 8 may be attributed to boulders common to end moraine.

(3) Bedrock Geology. The Clinton Harbor area is underlain by an early to mid-Palezoic sequence of igneous and slightly metamorphosed igneous rocks. The principal rock types are granite, tonalite, and amphibolite. The bedrock geology is shown on Plate 6.

The Haddam tonalite is composed essentially of plagioclase, quartz and hornblende and/or biotite. Accessory minerals include ilmenite, magnetite, apatite, garnet, and zircin. The rock is generally light gray in color with local bluish and yellowish areas. The grain size varies from fine to coarse although it is predominantly medium. Most of the tonalite has a widely spaced foliation produced by the parallel arrangement of biotite and/or hornblende.

The Clinton granite is composed essentially of microcline, quartz, plagioclase, and biotite. Accessory minerals include zircon, rutile, and traces of allanite and garnet. The granite is pink in color, medium to coarse-grained, and poorly foliated.

Amphibolite mixed with the tonalite is found in a zone along the contact between the tonalite and granite. The amphibolite is composed primarily of hornblende and plagioclase with small amounts of biotite and quartz. Common accessory minerals are sphene, magnetite or ilmenite, chlorite, garnet and apatite. The rock is commonly dark gray and is generally well-foliated.

The Haddam tonalite was emplaced earlier than the Clinton granite because of granite dikes within the tonalite. It is believed that the Clinton granite forms a dome-like structure within the tonalite, as is evidenced by the strikes of primarily foliation. The amphibolite zone most likely originated as a result of thermal metamorphism upon emplacement of the granite.

The subsurface investigation at Clinton Harbor did not recover bedrock; however, the Clinton granite directly underlies the project site. As previously noted, the refusal encountered in boring B and probe 8 may be top of bedrock or boulders common to glacial end moraine. The top of the rock surface at the site probably lies under at least 50 feet of overburden.

b. Black Ledge.

(1) Topography. The topography of the Black Ledge-Groton area is primarily controlled by bedrock, although glaciation has extensively modified the original topography. The region is characterized by hills corresponding to exposed bedrock and mounds of glacial till. Maximum elevation in the area is over 50 feet NGVD. The offshore area is generally flat, with numerous areas of resistant bedrock, such as Black Ledge, providing the relief. Minimum offshore elevation at the site is approximately -14 feet NGVD.

(2) Surficial Geology. In general, Pleistocene-age glacial deposits dominate the area, with recent deposits occurring in coastal and low-lying areas. Overburden cover in the area is quite variable, ranging between no cover to over 150 feet in thickness. The distribution of surficial materials is shown on Plate 6.

Glacial till in the area is compact, sandy and gravelly till grading into a loose sandy, gravelly, and bouldery till. Included in the till are lenses of stratified material. The till is found overlying bedrock, except in areas where bedrock is exposed. Till is exposed at the surface over most of the Groton-New London area.

Glacial stream deposits in the area consist of silt, sand, and gravel in valley fills, kame terraces and ice-channel fillings. These glacial stream deposits are similar to the ice-contact stratified drift and outwash deposits noted at Clinton. The stream deposits generally overlie the till. An extensive area of these stratified deposits is located in the area around Trumbull Airport.

In addition to glacially-derived overburden, there are areas of recent deposits. In the coastal areas, marsh and beach deposits are common. The marsh sediments consist of partly decomposed organic materials mixed or interbedded with estuarine silt and sand. They generally overlie glacial deposits and are exposed in large tracts around Trumbull Airport. The beach deposits consist chiefly of well-sorted sand deposited by current and wave action. Pebbly and gravelly areas are common. The beach deposits tend to overlie the marsh deposits. Primary locations are found at Osprey, Shennecossett, and Bushy Point Beaches.

Low-lying areas in areas of higher elevations have numerous swamp deposits. These consist of partly decomposed organic material mixed or interbedded with silt and sand. Swamp deposits generally overlie glacial till and are associated with recent alluvium. The alluvium is comprised of silt, sand, and gravel and is confined to the floodplains of present streams. Extensive tracts of land, primarily along the coast, have been filled. The fill is variable in composition from site to site, but in general, coarse sand and gravel are common fill materials.

Based on the borings and probes performed at Black Ledge, the thickness and nature of the overburden is quite variable. Thicknesses ranged from exposed bedrock to over 40 feet of cover. Up to 8 feet of recent organic, silty sand was recovered. Underlying this material was a sequence of compact gravel, sand, silt and varved clay, which may be glacial in origin. Refusals encountered by the probes are assumed to be bedrock and two of the five borings recovered bedrock samples.

(3) Bedrock Geology. The Black Ledge area is underlain by an early to late-Paleozoic sequence of igneous and metamorphic rocks. The principal rock types are granite, granodiorite, gneiss, and amphibolite. The bedrock geology is shown on Plate 6.

The Mamacoke Formation is a Cambro-ordovician sequence with two primary members. The lower unit consists of a distinctly to indistinctly-layered, light to dark gray, fine to medium-grained, biotite-quartz-plagioclase gneiss with minor schist and amphibolite. The upper member is a layered sequence of white to light gray, biotite-quartz-orthoclase gneiss; calc-silcate gneiss; amphibolite; biotite-quartz-andesine gneiss and garnet-rich, quartz-sillimanite-biotite-andesine gneiss; and coarse grained granular amphibolite.

The New London gneiss overlies the Mamacoke and has three primary units. The lower unit is an indistinctly-layered, hornblende-biotite-quartz-plagioclase gneiss. The middle unit is a light gray, medium to fine-grained, massive, gneissic granodiorite, with local quartz monzonite. The upper unit consists of interlayered, light gray, granodioritic gneiss and amphibolite, with subordinate hornblende-plagioclase gneiss, alaskite, and granite gneiss.

The Monson gneiss overlies the New London gneiss. It is a gray to dark gray, medium to coarse-grained, distinctly to indistinctly layered, locally massive, hornblende-biotite-quartz-plagioclase gneiss. Small lenses and layers of alaskite and amphibolite are present.

The Alaskite gneiss is a member of the Mississippian-age Sterling Plutonic Group. It is an orange-pink, light tan to white, locally iron-stained, mostly fine-grained, indistinctly foliated granite and a fine to medium grained, well foliated granite gneiss. They occur in both concordant and discordant masses.

These rock formations are contained in a N50 W-trending, overturned anticline. The rocks in the project area are on the overturned limb, giving the impression that the older rocks overlie the younger ones. Foliation dip in the rocks ranges between 30° and 70°, but generally averages 50° to the north.

Bedrock samples were obtained from two of the borings. Boring A consisted of 1 foot of a light-gray, medium-grained, hornblende-biotite-quartz-feldspar gneiss grading downward to a granite. The two inch recovery in boring D revealed a light gray, medium-grained granite. Tentatively, the gneiss is assigned to the New London Formation and the granite is assigned to the Alaskite Gneiss Formation. Petrographic analysis of the samples will be performed in later stages of the study.

6. Foundation Conditions.

a. Clinton Harbor. As shown on Plate 3 (Clinton Harbor Site, Clinton, CT) the retention dike alignment extends from the West Shore of the harbor approximately 1,600 feet eastward to boring FD-C, then northeasterly 1,200 feet to boring FD-B, then approximately 2,000 feet north to the north shore of the harbor.

The ground elevation within the proposed retention dike alignment varies from mean high water (+2.75 NGVD) at the shoreline to about 7 feet below mean low water (-9.0 NGVD) at borings FD-C and FD-B.

As shown on the soil profile, Plate 3 and the Summary of Test Results, Plate 1, soil conditions in the foundation area consist of surficial deposits of granular soil overlying very soft organic silt of undetermined depth. The granular soil is predominantly loose, medium to fine sand with shell fragments interbedded with deposits of loose to moderately-compact, silty sand and moderately-compact gravelly sand. The depth of sand deposits vary from 7 feet thick at FD-A to 30 feet at FD-C. Standard penetration test values in the medium to fine sand range from zero (push) to 9 and averages about 7 blows per foot. The underlying fine grain soils consist of very soft, fine-sandy, organic silt (OL & OH) with shell fragments and peat fibers. Borings FD-A and FD-C, driven to depth of 40 feet, did not reach the bottom of the silt deposit. At boring FD-B the organic silt deposit was encountered at a depth of 21 feet and refusal at 26 feet. Standard penetration test values in the organic silt range from zero (push) to 3 blows per foot.

b. Black Ledge. As shown on Plate 4 (Black Ledge Site, Groton, CT) the retention dike alignment extends completely around Black Ledge located about 3,000 feet south from Avery Point and 2,500 feet east of the New London Harbor Navigation Channel. The proposed dike alignment extends southerly from boring FD-A approximately 2,000 feet to probe P-20, then turning and running southeasterly 2,400 feet to point C, from point C the dike extends northeasterly 1,650 feet to point B, then turning northwesterly for 3,200 feet back to boring FD-A.

The ground elevation along the proposed retention dike alignment varies from -10 feet MLW to -33 feet MLW with the average depth of -20.5 feet MLW (-21.5 feet NGVD).

As shown on the Soil Profile, Plate 4, and Summary of Soil Test Results, Plate 2, soil conditions in the foundation area consist of a surficial deposit of very loose silty sand with shell fragments and plant matter ranging in depth from 1 to 6 feet deep with standard penetration test values of zero (push). This deposit continues with slightly more consolidation from a depth of 2 to 6 feet with standard penetration test values ranging from 3 to 7 blows per foot.

In general, the surficial deposits are underlain by a stratum of moderately compact, granular soil ranging from fine sand (SP) to silty, gravelly sand (SM). This deposit ranges in depth from 4 to 12 feet with standard penetration values ranging from 14 to 100 blows per foot and averaging about 30 blows per foot.

Along the westerly half of the containment area (probe P-3 to probe P-21), the granular soil overlies very dense, silty, gravelly sand or bedrock. Probes P-2, P-3, P-20, and P-21 all hit refusal at depths from 2 to 11 feet below the ground surface. Bedrock was encountered in borings FD-A and FD-D at depths of 14 and 10 feet, respectively.

In the eastern half of the area, boring FD-B and FD-C extended 40 feet below ground surface without encountering bedrock. The moderately-compact, fine sand and silty, gravelly sand in this area overlies moderately-compact, inorganic silt (ML). With increasing depth this grades into moderately-stiff, silty clay (CL). Standard penetration test values in this fine-grained soil range from 9 to 85 blows per foot and average about 20 blows per foot. In boring FD-C, silty, gravelly sand was encountered below the silt zone at a depth of 33 feet, probably indicating that the bedrock surface is nearby.

7. Retention Dike Design.

a. Clinton Harbor (Typical Dike Cross Sections, Plate 8)

(1) Design Considerations.

(a) The containment dike crest elevation (+6.0 MLW) and the flatness of the side slopes (1 vertical on 2.5 horizontal) are based on stability considerations due to the soft foundation conditions.

(b) The method of placement of the dike material is dictated by the shallow water depth which rules out barge placement.

(c) The material selected for the dike core (quarry spalls) must be strong enough to support the trucking and placement equipment and resist erosion from tidal fluctuations during construction. This material may be too pervious to satisfactorily retain suspended sediments in the containment area. To alleviate this condition, a gravel layer 18 inches thick will be placed on the containment side slope to blanket the quarry spalls and if necessary, plastic filter fabric will be placed over the gravel blanket when depositing dredged material.

(d) Slope protection requirements on the ocean side of the dike are dictated by design wave heights (4 and 6 feet).

(e) Crest and landside slope protection against wave action and overtopping from the design waves. The crest of the dike is protected by extending the rock slope protection over the top; however, the gravel blanket placed on the containment side slope to retain dredge material fines may be damaged by overtopping waves. It is expected that periodic maintenance will be required to replenish the gravel blanket until the containment area is filled.

(2) Dike Stability. The dike crest elevation and side slopes were analyzed for stability using the wedge method of planes and criteria described in EM 1110-2-5008 dated 15 October 1980. The assumed design strengths for the 6 feet above mean low water (+4 NGVD) with side slopes 1 vertical on 2.5 horizontal provides a factor of safety for stability of 1.3 which is the minimum factor of safety recommended in EM 1110-2-5008 for the end of construction condition.

Stability analyses were run assuming an embankment core material of bank run gravel with an angle of internal friction of 30 degrees, however, the dike design was later revised using a core material of quarry spalls. Additional stability analyses were not run on the revised dike as the quarry spalls are assumed to have a friction angle greater than 30 degrees and a stability analysis would result in a factor of safety greater than 1.3 which was obtained with the bank run gravel.

TABLE I

MATERIAL	UNIT WEIGHT (lbs/FT^3) Sat.	Sub.	SHEAR STRENGTH ϕ	C(lbs/FT^2)
Emb. - bank run gravel	130	65	30°	0
Fdn. - loose sand	-	55	25°	0
Fdn. - soft organic silt	-	45	0	200 psf

(3) Construction Considerations. Hauling of the core material will be by truck from land borrow areas. Placement will be by dumping from the trucks and spreading by bulldozer, starting from shore and progressing outward. The top of the core material will be maintained at elevation +3 MLW (+1 NGVD) which is about 2 feet below mean high tide and will require a work schedule coordinated with the tide movement. After the dike core is placed, riprap slope protection will be placed by crane operating from the dike core at elevation 3 MLW. Source of core material and slope protection will be quarry rock hauled by truck overland from quarries within an estimated 30 mile radius of the site.

(4) Slope Protection. Stone sizes for the slope protection on the ocean side of the dike were determined from criteria set forth in the Coastal Engineering Research Center (CERC) Shore Protection Manual and Coastal Engineering Note TN 111-1, Riprap Revetment Design. Slope protection was designed for two wave heights for which different portions of the alignment will be subjected, i.e. H of 4 feet and 6 feet overtopping of the dike (elev. 6 MLW) (+4 NGVD) will occur with waves of this magnitude. The crest of the dike will be protected against erosion from overtopping by extending the slope protection over the top of the dike. Erosion of the gravel blanket on the containment side slope is likely to occur from overtopping waves of the design magnitude and periodic maintenance to replenish the gravel blanket should be anticipated.

b. Black Ledge (Typical Dike Cross Sections, Plates 9 and 10).

(1) Design Considerations.

(a) The proposed retention dike will be built in 5 to 35 feet of water.

(b) The core material must have a gradation capable of retaining the suspended dredge material within the containment area.

(c) The elevation to which the core material is carried dictates the quantity of dredge material that can be disposed at the site for a given alignment.

(d) The depth of water (5 to 35 feet) and distance offshore (1/2 mile) necessitates transport of all construction materials by barge.

(e) Slope protection requirements are dictated by design wave heights and overtopping potential.

(2) Dike Stability. Dike cross sections were analyzed for stability using the wedge method of planes and criteria described in EM 1110-2-5008 dated 15 October 1980. The assumed design strengths for the foundation and embankment materials are shown on Table II. Typical retention dike cross sections as shown on Plates 8 and 9 were designed to exceed a minimum factor of safety for stability of 1.3 as recommended in EM 1110-2-5008 for the end of construction condition.

TABLE II

MATERIAL	UNIT WEIGHT (lbs/FT^3) Sat.	Sub.	SHEAR STRENGTH ϕ	C(lbs/FT^2)
Emb. - rock core material	130	65	40	0
Fdn. - compact sand	-	60	33	0
Fdn. - loose sand	-	55	30	0
Fdn. - loose silt	-	45	0	0

(3) Construction Considerations. The rock core material, as well as the stone slope protection, will be supplied from coastal quarries located within a 40 mile radius of Black Ledge, all materials will be transported by water-borne barges. Placement of the core material will be by bottom dump barges to about elevation -10 feet MLW (-11 NGVD). Above this elevation, placement will be by cranes operating from floating barges. The crest elevation of the core will be maintained at +6 MLW (+5 NGVD) which will provide 3 feet of free board above the mean high water level. Once a section of the core has been completed, the required bedding stone layers and stone slope protection will be placed by crane operating from floating barges adjacent to the dike.

(4) Slope Protection. Stone sizes for the slope protection system were determined from criteria set forth in the Coastal Engineering Research Center (CERC) Shore Protection Manual and Coastal Engineering Technical Note TN III-I, Riprap Revetment Design. Slope protection was

designed for two design wave heights (H) of 4 ft. and 6 ft. which different portions of the proposed alignment will be subjected. Overtopping of the dike will occur with waves of this magnitude. To protect the dike against overtopping the slope protection will be placed over the crest and down the inside slope of the retention dike to an elevation of -6 feet MLW (-7 NGVD). Typical dike sections are shown on Plates 8 and 9.

8. Construction Materials.

a. Clinton Harbor. Based upon preliminary estimates, the following material will be required to construct the Clinton Harbor containment facility:

CONSTRUCTION MATERIALS, CLINTON HARBOR SITE (Revised)

MATERIAL	QUANTITY
1,000 - 1,500 lb. Armor Stone	13,100 c.y.
200 - 400 lb. Armor Stone	4,900 c.y.
1 - 150 lb. Quarry Chips	44,750 c.y.
Gravel (bank run)	3,000 c.y.

The quarried rock material of suitable quality and sufficient resistance to weathering and disintegration is available from commercial suppliers within a 30 mile radius of the study site. Gravel material in the quantity needed is available from several developed and undeveloped sources within a 30 mile radius of the site.

b. Black Ledge. Based upon preliminary estimates, the following material will be required to construct the Black Ledge containment facility:

CONSTRUCTION MATERIALS, BLACK LEDGE SITE (Revised)

MATERIAL	QUANTITY
1,000 - 2,000 lb. Armor Stone	88,800 cy
300 - 600 lb. Armor Stone	27,000 cy
100 - 200 lb. Underlayer Stone	162,600 cy
30 - 60 lb. Underlayer Stone	42,000 cy
Quarry spalls to 50 lb.	883,800 cy

The quarried rock material of suitable quality and sufficient resistance to weathering and disintegration is available from commercial suppliers within a 40 mile radius of the study site. It may be necessary to obtain the desired quantity of quarry spalls from a combination of suppliers.

9. Conclusions and Recommendations.

a. Poor foundation conditions exist at both the proposed Clinton Harbor and Black Ledge dredge containment sites. The originally proposed alignments at both sites were altered to avoid deep water and 5 to 7 feet of soft soil (0 blow counts) at the Clinton site and up to 12 feet of soft soil (0 to 7 blow counts) at Black Ledge site.

b. Both the Clinton Harbor and Black Ledge sites will be subjected to large wave heights. The design wave heights are 6 feet at both sites.

c. Portions of the proposed Black Ledge retention dike alignment are in 35 feet of water. The depth of water in combination with design considerations for the large wave heights makes for a very large and expensive retention dike cross section.

d. Future siting of proposed dredge containment facilities should consider design wave heights for the particular site, available subsurface information, depth of water (if applicable) and construction methods (standard earth moving or barge construction).

e. Recommendation is made that prior to final design of Clinton Harbor or Black Ledge dredge containment facilities that a detailed subsurface exploration and soil testing program be carried out to refine the proposed alignments economizing the embankment cross sections.

COST ESTIMATE
BLACK LEDGE CONTAINMENT DIKE
GROTON, CONNECTICUT

ITEM	QUANTITY NUMBER UNITS	QUANTITY UNIT MEASURE	MATERIAL PER UNIT	MATERIAL TOTAL	TOTAL COST
BORING FD-A TO PROBE P-21 (2,900 L.F.)					
Quarry Spalls	400,690	C.Y.	$18.00	$7,212,420	
Underlayer Stone	90,625	C.Y.	$35.00	3,171,875	
Armor Stone	42,695	C.Y.	$65.00	2,775,175	
					$13,159,470
PROBE P-21 TO POINT C (1,500 L.F.)					
Quarry Spalls	127,100	C.Y.	$18.00	$2,287,800	
Underlayer Stone	22,990	C.Y.	$35.00	804,650	
Armor Stone	22,085	C.Y.	$65.00	1,435,525	
					$ 4,527,975
POINT B TO POINT C (1,650 L.F.)					
Quarry Spalls	174,000	C.Y.	$18.00	$3,132,000	
Underlayer Stone	49,000	C.Y.	$35.00	1,715,000	
Armor Stone	24,000	C.Y.	$65.00	1,560,000	
					$ 6,407,000
BORING FD-A TO POINT B (3,200 L.F.)					
Quarry Spalls	182,000	C.Y.	$18.00	$3,276,000	
Underlayer Stone	42,000	C.Y.	$35.00	1,470,000	
Armor Stone	27,000	C.Y.	$65.00	1,755,000	
					$ 6,501,000
TOTAL					$30,595,445

COST ESTIMATE
CLINTON HARBOR CONTAINMENT DIKE
CLINTON, CONNECTICUT

ITEM	QUANTITY NUMBER UNITS	QUANTITY UNIT MEASURE	MATERIAL PER UNIT	MATERIAL TOTAL	TOTAL COST
WEST SHORE TO M.L.W. (800')					
Armor Stone (1000-1500 lbs.)	1,822	C.Y.	$35.00	$63,770	
Quarry Chips	2,352	C.Y.	$15.00	35,280	
Gravel Fill	30	C.Y.	$10.00	300	
					$ 99,350
M.L.W. TO PROBE P-11 (200')					
Armor Stone (1000-1500 lbs.)	745	C.Y.	$35.00	$26,075	
Quarry Chips	1,583	C.Y.	$15.00	23,745	
Gravel Fill	104	C.Y.	$10.00	1,040	
					$ 50,860
PROBE P-11 TO BH-B (1900')					
Armor Stone (1000-1500 lbs.)	10,561	C.Y.	$35.00	$369,635	
Quarry Chips	29,407	C.Y.	$15.00	441,105	
Gravel Fill	2,148	C.Y.	$10.00	21,480	
					$ 832,220
BORING BH-B TO BH-A (800')					
Armor Stone (200-400 lbs.)	2,326	C.Y.	$35.00	$ 81,410	
Quarry Chips	6,430	C.Y.	$15.00	96,450	
Gravel Fill	474	C.Y.	$10.00	4,740	
					$ 182,600
BORING BH-A TO NORTH SHORE (1200')					
Armor Stone (200-400 lbs.)	2,563	C.Y.	$35.00	$ 89,705	
Quarry Chips	4,980	C.Y.	$15.00	74,700	
Gravel Fill	248	C.Y.	$10.00	2,480	
					$ 166,885
TOTAL					$1,331,915

SELECTED REFERENCES

1. Department of the Army, 1980, Engineer Manual EM 1110-2-5008, Design and Construction of Retaining Dikes for Containment of Dredged Material.

2. U. S. Army Coastal Engineering Research Center, 1977, Shore Protection Manual.

3. U. S. Army Coastal Engineering Research Center, 1979, Technical Note III-I Riprap Revetment Design.

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10. Schairer, J. F., 1931, The Minerals of Connecticut. State Geologic and Natural History Survey, Bulletin No. 51, 117 pp.

SOIL TESTS RESULTS

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm	ATT. LIMITS LL	PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND. AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.	% Organic
FD-A	-3.4	5-1	0.0-2.0	SP	1	98	1	0.15	NP	-												
		5-2	5.0-7.0	SP-SM	0	92	8	0.08	NP	-												
		5-3	11.0-13.0	OL	0	36	64	0.006	36	26	2.68	40										
		"	" "	OL					NP.													
		5-4	15.0-17.0	OH	0	17	83	<.001	67	39	2.71	73										2.65
		"	" "	OH					53d	35d												
		5-5	22.022.0	OH	0	8	92	<.001	79	37	2.63	88										
		5-6	33.0-35.0	OH	0	3	97	<.001	116	59	2.53	112										4.94
		5-7	38-40.0	OH	0	2	98	<.001	117	60	2.54	116										
FD-B	-6.9	5-1	0.0-2.0	SP	1	97	2	0.110	-	-												
		5-2	5.0-7.0	SC	0	75	25	0.010	31	21	2.70	29										
		5-3	13.0-15.0	SP	0	100	0	0.350	-	-												
		5-5	23.0-25.0	OH	0	18	82	<.001	117	58	2.69	120										
FD-C	-9.1	5-2	6.0-8.0	SP-SM	3	89	8	0.10	-	-	-	-										
		5-3	11.0-13.0	SP	38	57	5	0.13	-	-	-	-										
		5-5	30.0-32.0	OH	0	45	55	0.002	53	32	2.66	63										
		5-6	36.0-38.0	OH	0	12	88	<.001	78	38	2.63	58										3.5
		5-7	40.0-42.0	OL	0	36	64	.0015	49	29	2.70	67										
		"	" "	OL					39d	27d												

Elevation Datum is NGVD.
53d- LL&PL on oven-dry sample

NED FORM JUL 63 510 * PROVIDENCE VIBRATED DENSITY TEST

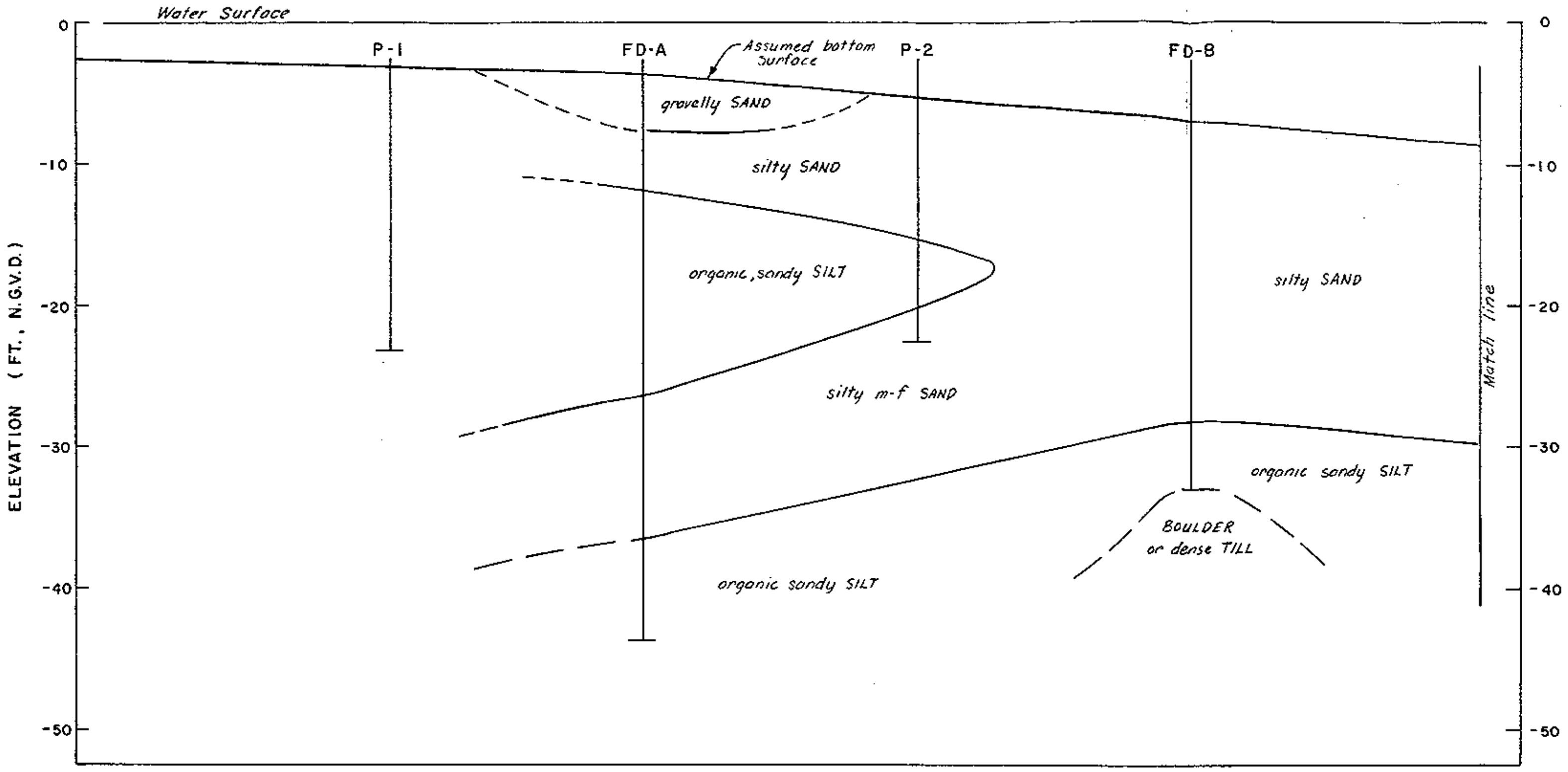
Clinton Harbor Site, Clinton, CT

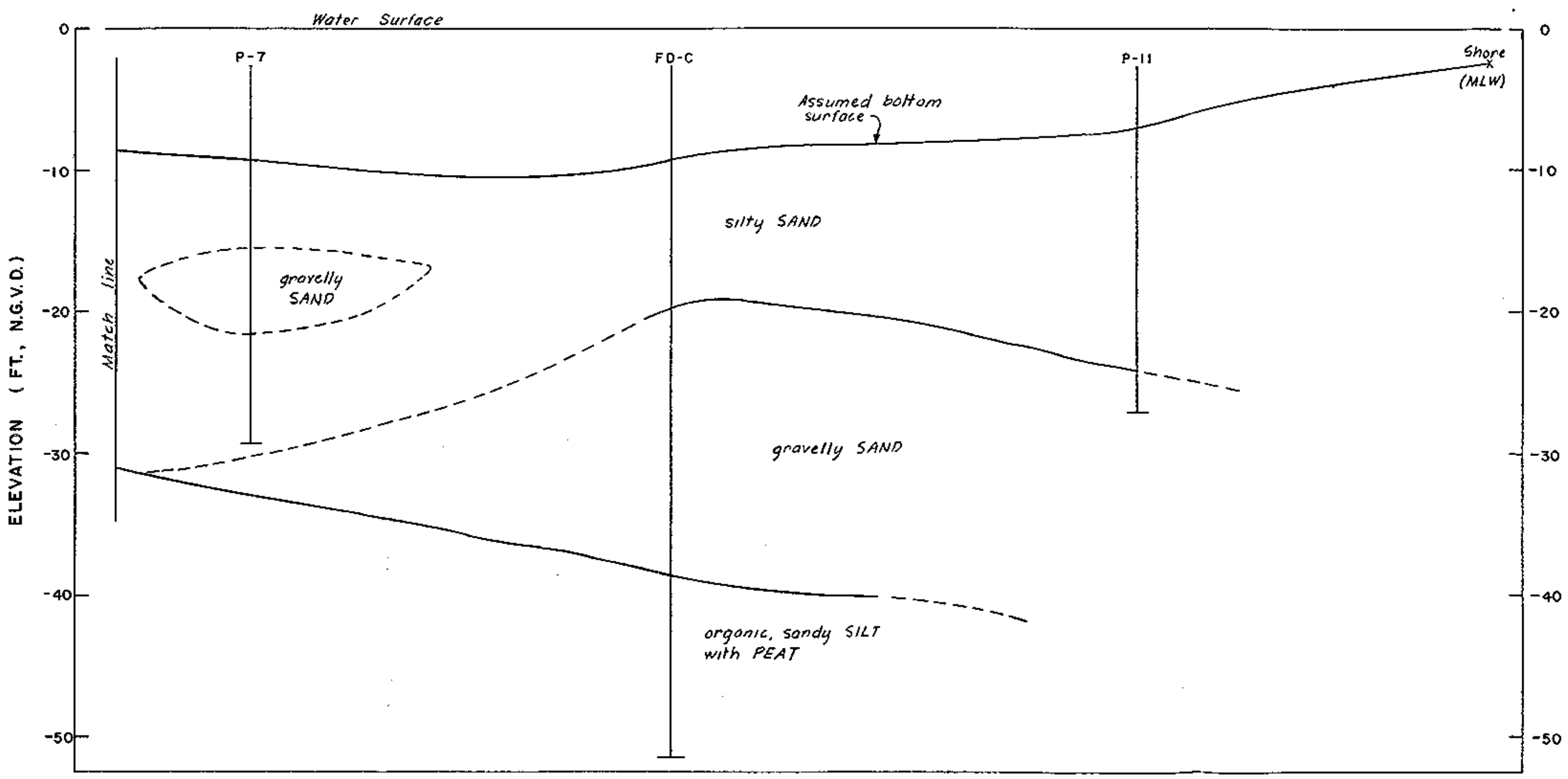
Plate 1

SOIL TESTS RESULTS

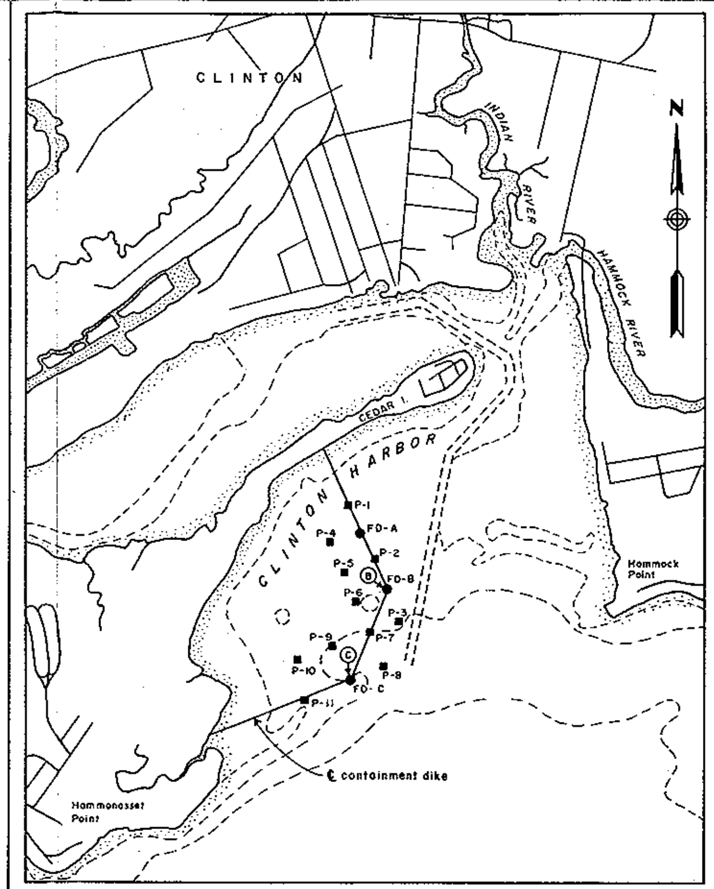
EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS: GRAVEL %	MECHANICAL ANALYSIS: SAND %	MECHANICAL ANALYSIS: FINES %	MECHANICAL ANALYSIS: D_{10} mm.	ATT. LIMITS: LL	ATT. LIMITS: PL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT: TOTAL	NAT. WATER CONTENT % DRY WT: -NO4	COMPACTION DATA STND. AASHO: OPT. WATER % DRY WT	COMPACTION DATA STND. AASHO: MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT: TOTAL	NAT. DRY DENSITY LBS/CU FT: -NO4	OTHER TESTS: SHEAR	OTHER TESTS: CONSOL.	OTHER TESTS: PERM.
FD-A	-25.5	S-1	1.5-3.5	SM	29	57	14	0.04													
		S-2	5.5-7.5	SP	7	90	3	0.14													
		S-3	10.0-12.0	SM	30	50	20	0.03													
FD-B	-18.5	S-1	2.5-4.5	SM	1	55	44	-													
		S-2	6.5-8.5	SP	1	97	2	0.23													
		S-3A	12.5-13.5	SP	3	93	4	0.15													
		S-4	17.0-19.0	ML	0	17	83	0.015			2.68										
		S-5	22.5-24.5	ML	0	2	98	0.004	NP	NP	2.75	30.1									
		S-6	28.0-30.0	ML	0	4	96	0.002	27	22	2.73	32.7									
		S-7	33.0-35.0	OL	0	3	97	0.001	33	23	2.75	29.2									
		S-8	38.0-40.5	CL	0	5	95	0.001	30	21	2.75	33.2									
FD-C	-27.0	S-1	2.5-5.5	SC	26	56	18	-													
		S-2A	11.0-12.0	SP	37	62	1	0.30													
		S-2B	12.0-13.0	ML	0	4	96	0.007													
		S-3	15.5-17.5	ML	0	4	96	0.005	NP	NP	2.74	27.7									
		S-4	20.5-22.5	ML	0	3	97	0.001	29	27	2.70	31.6									
		S-5	25.5-27.5	CL	1	2	98	0.002	31	21	2.76	30.5									
		S-6	31.0-33.2	ML	36	15	84	0.003	NP	NP	2.70	26.1									
		S-7	33.2-40.5	SM		40	24	-													
FD-D	-27.0	S-1	1.0-3.0	GP-GM	50	38	12	-													
		S-2	6.0-8.8	SM	32	52	16	0.03													
FD-E	-30.0	S-1	0.0-6.0	ML	0	14	86	0.002													

CORPS OF ENGINEERS U. S. ARMY





PROFILE ALONG PERIPHERY OF DIKE ALIGNMENT



LOCATION MAP AND PLAN OF EXPLORATIONS

NOTES
- ■ PROBE
- ● BORING
- Ⓑ CONTAINMENT FACILITY CORNER

GRAPHIC SCALE
500 0 500 1000 FT.

NOTE
For Graphic Logs see Plate 5.

GRAPHIC SCALES
HORIZ. 100' 0' 100' 200'
VERT. 5' 0 5' 10'

0.0 MLW = -1.95 N.G.V.D.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

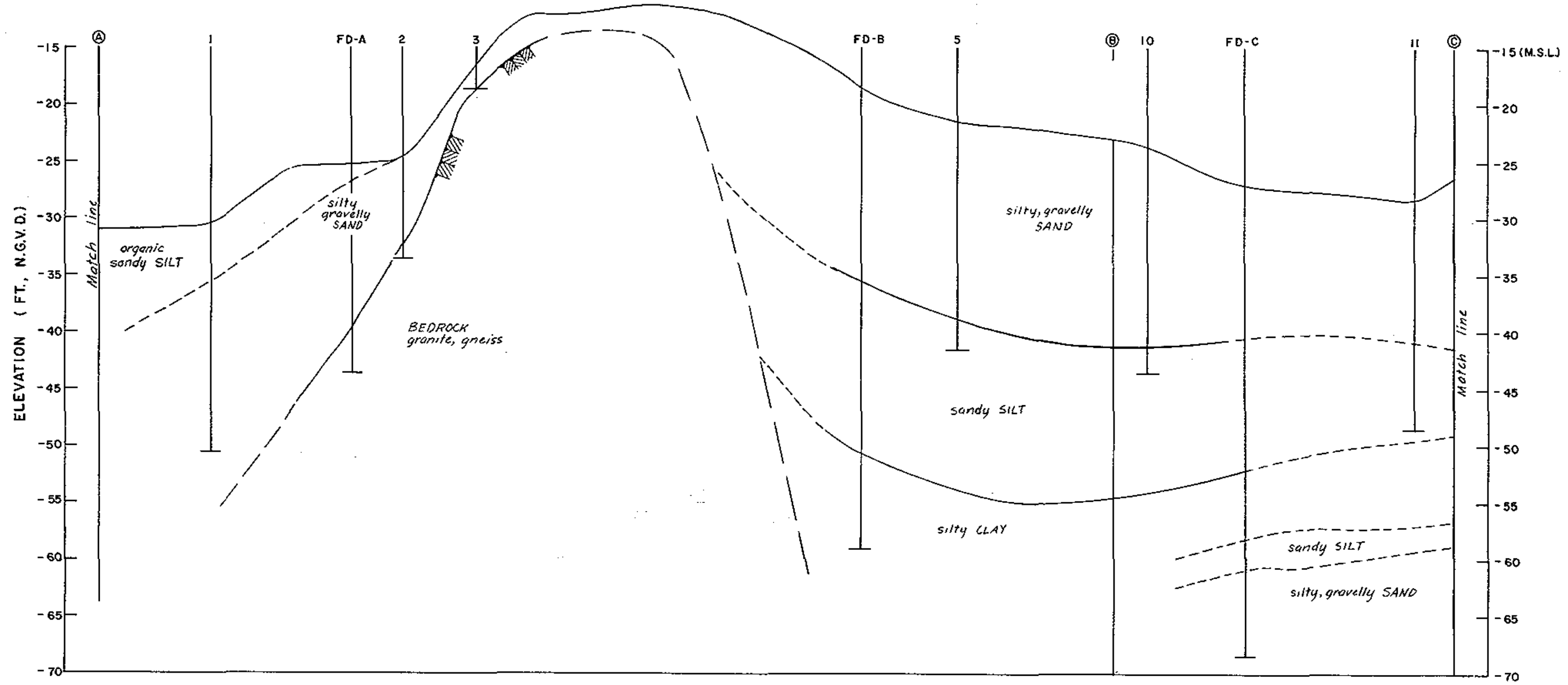
DES. BY:
DR. BY:
CK. BY:

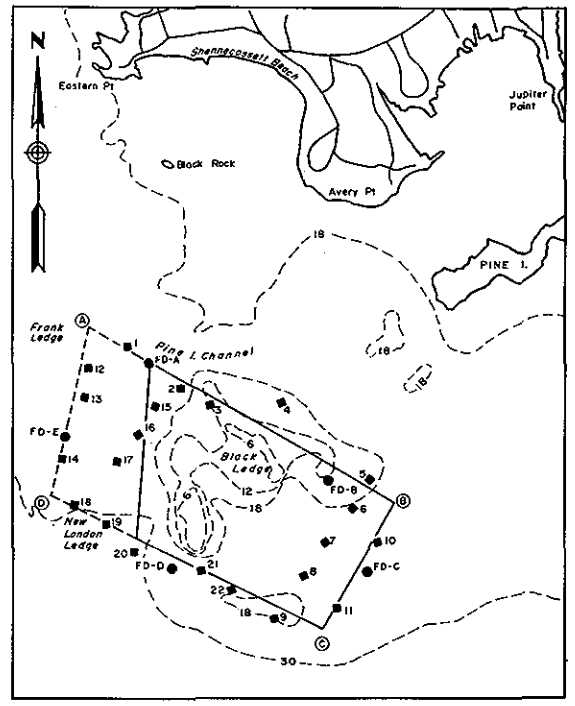
LONG ISLAND SOUND
DREDGE MATERIAL
CONTAINMENT STUDY
PLAN OF EXPLORATIONS AND PROFILE
PROPOSED CLINTON HARBOR SITE
CLINTON, CT.

GEOTECH. ENG. BR.
PLATE 3

SCALE: AS SHOWN
DATE: APRIL 1982

CORPS OF ENGINEERS U. S. ARMY



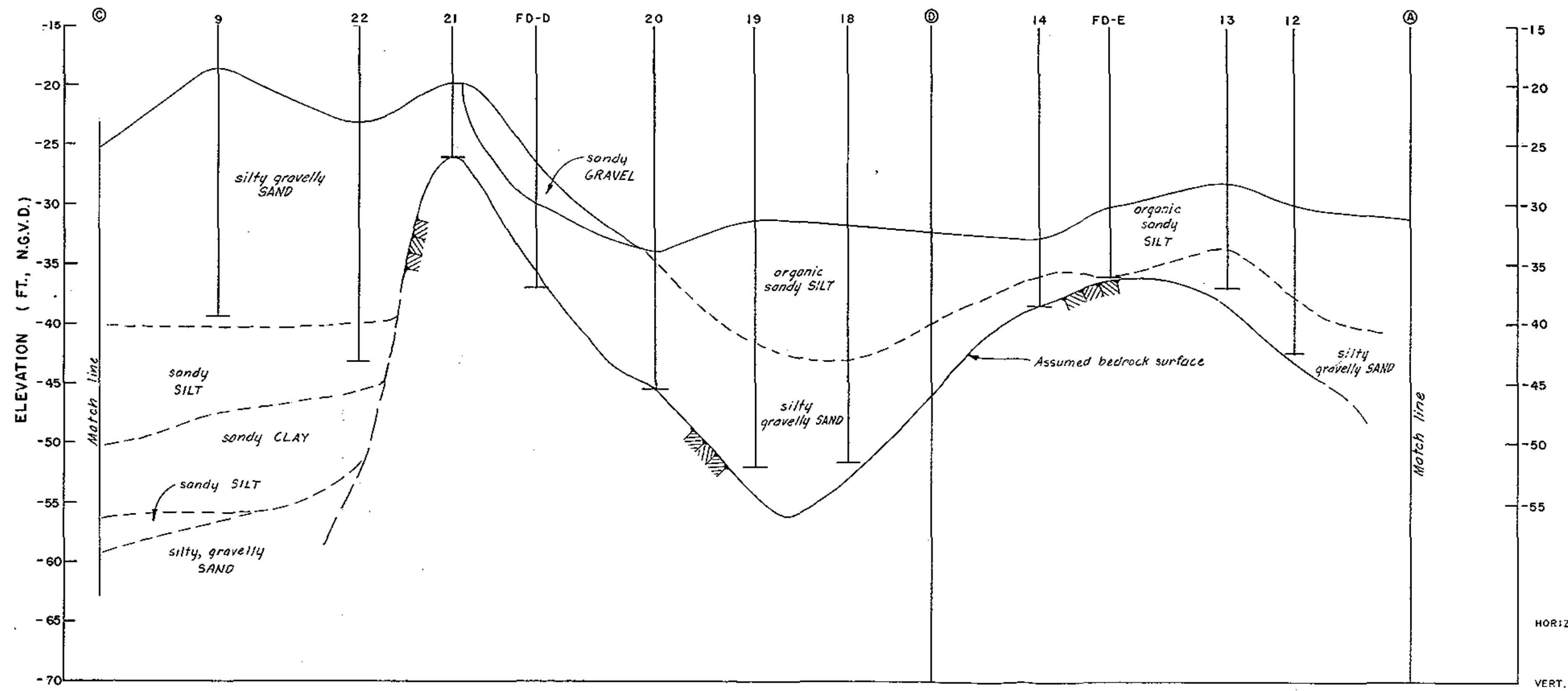


LOCATION MAP AND PLAN OF EXPLORATIONS

NOTES

- ■ PROBE
- ● BORING
- Ⓑ CONTAINMENT FACILITY CORNER
- ----ORIGINAL ALINEMENT CHANGED DUE TO FOUNDATION CONDITION

GRAPHIC SCALE 500 0 500 1000 FT.



PROFILE ALONG PERIPHERY OF DIKE ALIGNMENT

NOTE
For Graphic Logs see Plate 7.

GRAPHIC SCALES

HORIZ. 250' 0 250' 500'

VERT. 5' 0 5' 10'

0.0 MLW = 4.05 N.G.V.D.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

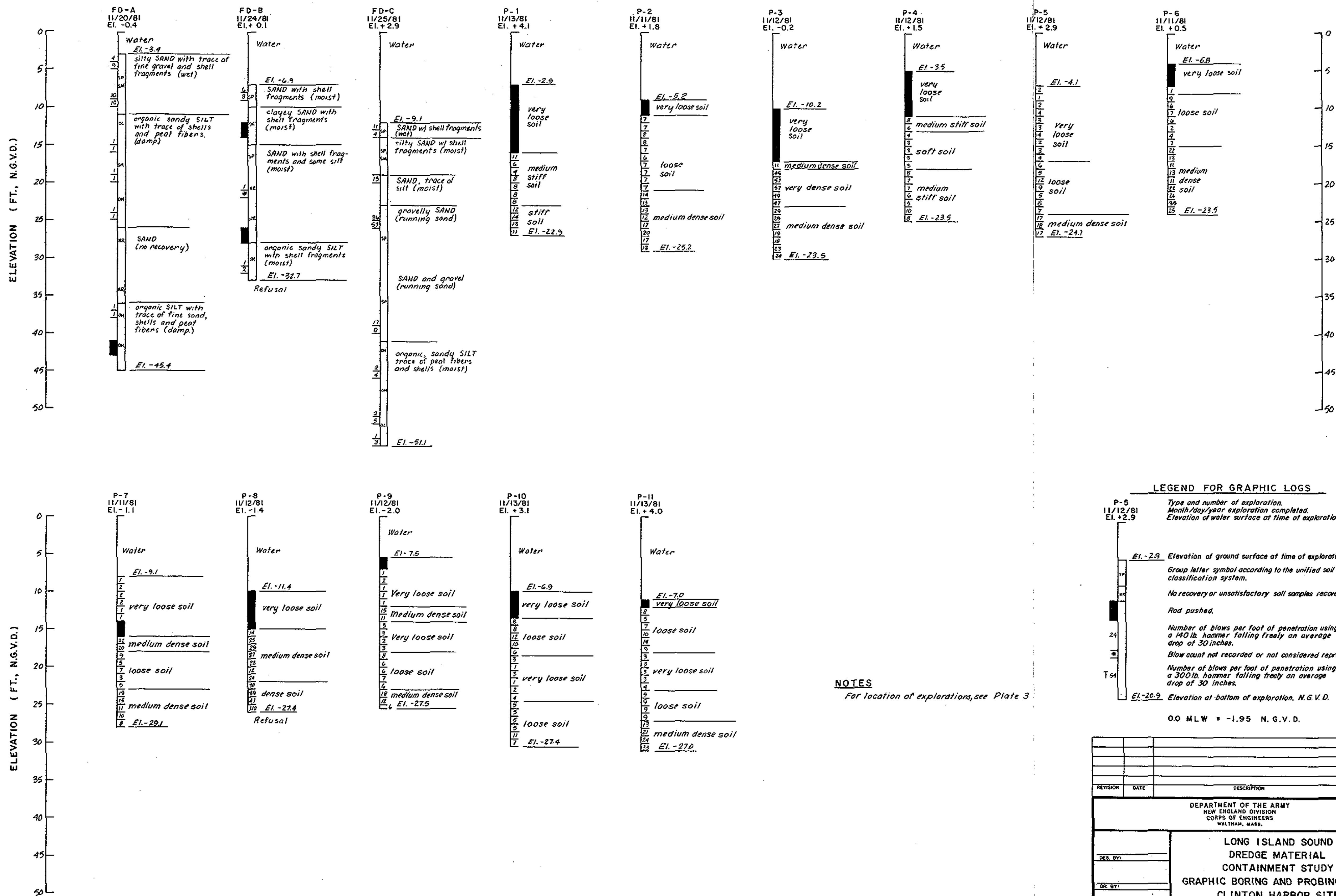
DES. BY:
DR. BY:
CK. BY:

LONG ISLAND SOUND
DREDGE MATERIAL
CONTAINMENT STUDY
PLAN OF EXPLORATIONS AND PROFILE
PROPOSED BLACK LEDGE SITE
GROTON, CT.

GEOTECH. ENG. BR.
PLATE 4

SCALE: AS SHOWN
DATE: APRIL 1982

CORPS OF ENGINEERS | U. S. ARMY



NOTES

For location of explorations, see Plate 3

LEGEND FOR GRAPHIC LOGS

P-5 11/12/81 El. +2.9 — Type and number of exploration. Month/day/year exploration completed. Elevation of water surface at time of exploration. N.G.V.D.

El. -2.9 — Elevation of ground surface at time of exploration. N.G.V.D.

SP — Group letter symbol according to the unified soil classification system.

NR — No recovery or unsatisfactory soil samples recovered.

Rod pushed.

24 — Number of blows per foot of penetration using a 140 lb. hammer falling freely an average drop of 30 inches.

Blow count not recorded or not considered representative.

T54 — Number of blows per foot of penetration using a 300 lb. hammer falling freely an average drop of 30 inches.

El. -20.9 — Elevation at bottom of exploration. N.G.V.D.

0.0 MLW = -1.95 N.G.V.D.

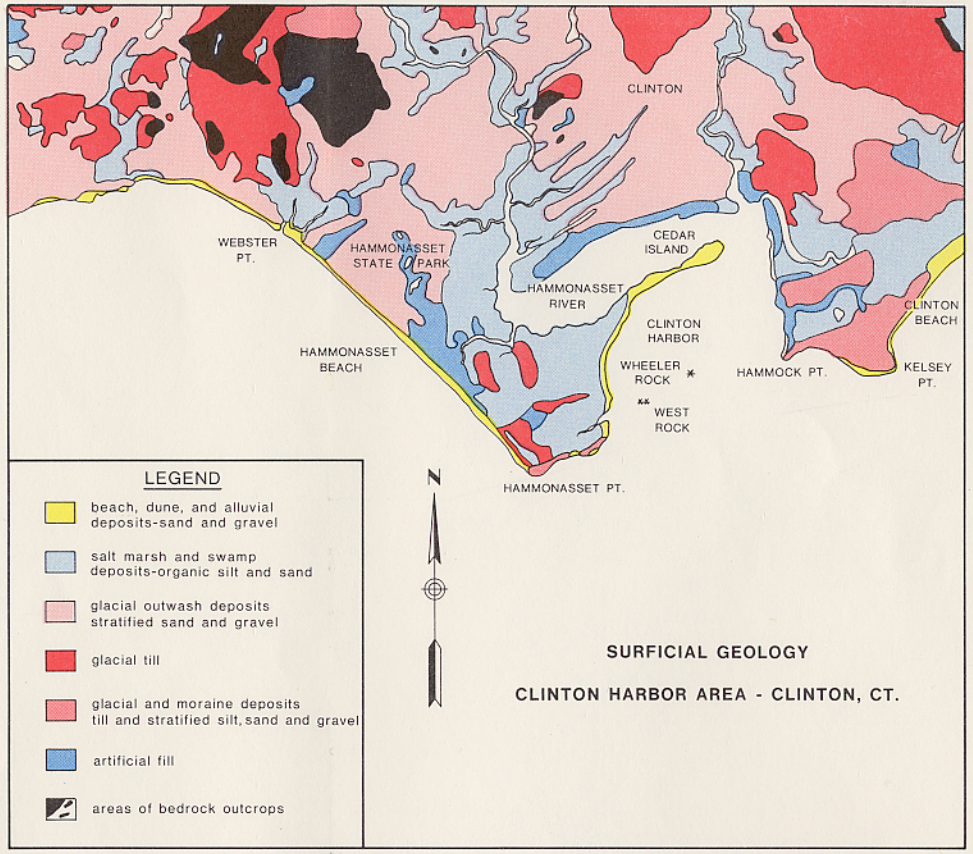
REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY:
DR. BY:
CK. BY:

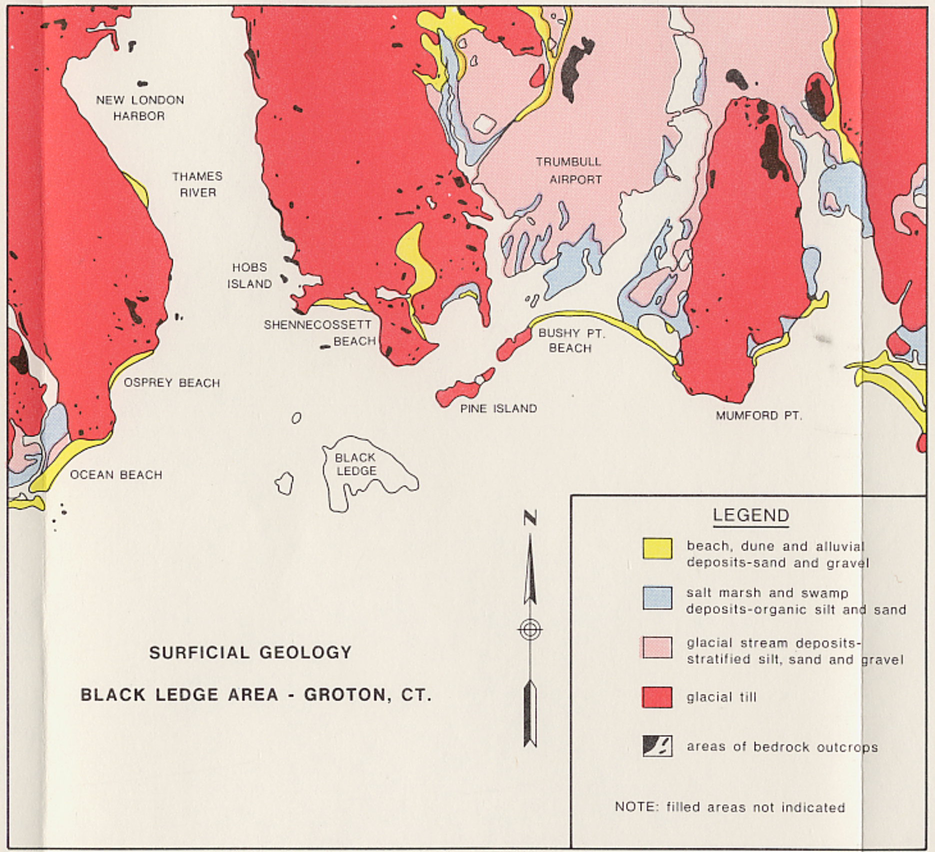
LONG ISLAND SOUND
DREDGE MATERIAL
CONTAINMENT STUDY
GRAPHIC BORING AND PROBING LOGS
CLINTON HARBOR SITE
CLINTON, CT.

GEOTECH. ENG. BR. | SCALE: AS SHOWN
PLATE 5 | DATE: APRIL 1982



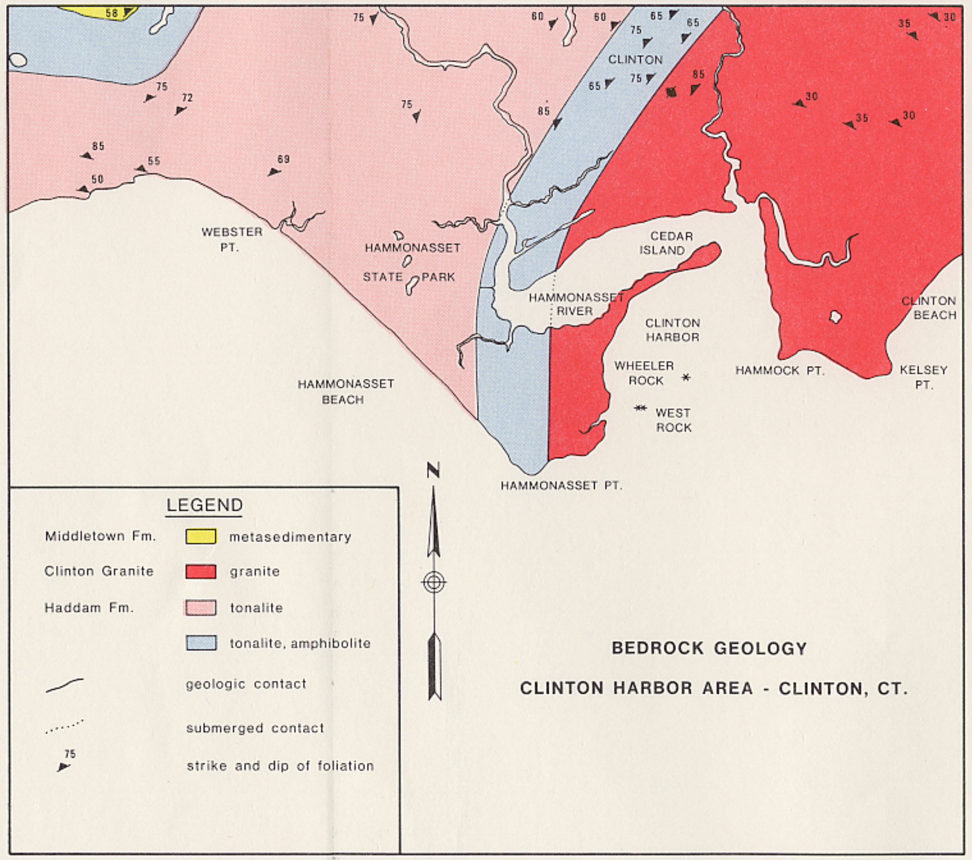
SURFICIAL GEOLOGY

CLINTON HARBOR AREA - CLINTON, CT.



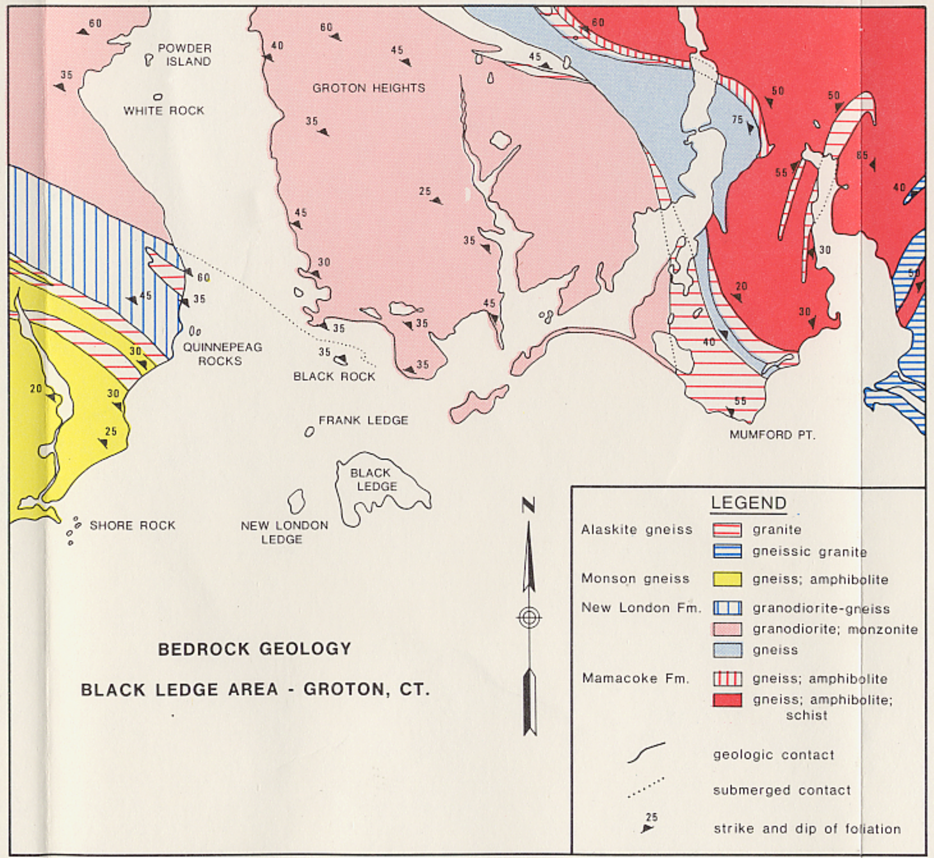
SURFICIAL GEOLOGY

BLACK LEDGE AREA - GROTON, CT.



BEDROCK GEOLOGY

CLINTON HARBOR AREA - CLINTON, CT.



BEDROCK GEOLOGY

BLACK LEDGE AREA - GROTON, CT.

GRAPHIC SCALE

2000 0 2000 4000

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY EB	DR. BY EB	CK. BY

SUBMITTED: CHIEF, SECTION

APPROVAL RECOMMENDED: CHIEF, DESIGN BRANCH

REVIEWED: PROJECT MANAGER

APPROVAL RECOMMENDED: CHIEF, PROJECT MNGT. BRANCH

LONG ISLAND SOUND, CT.
BLACK LEDGE, CLINTON HBR.
GEOLOGIC MAPS

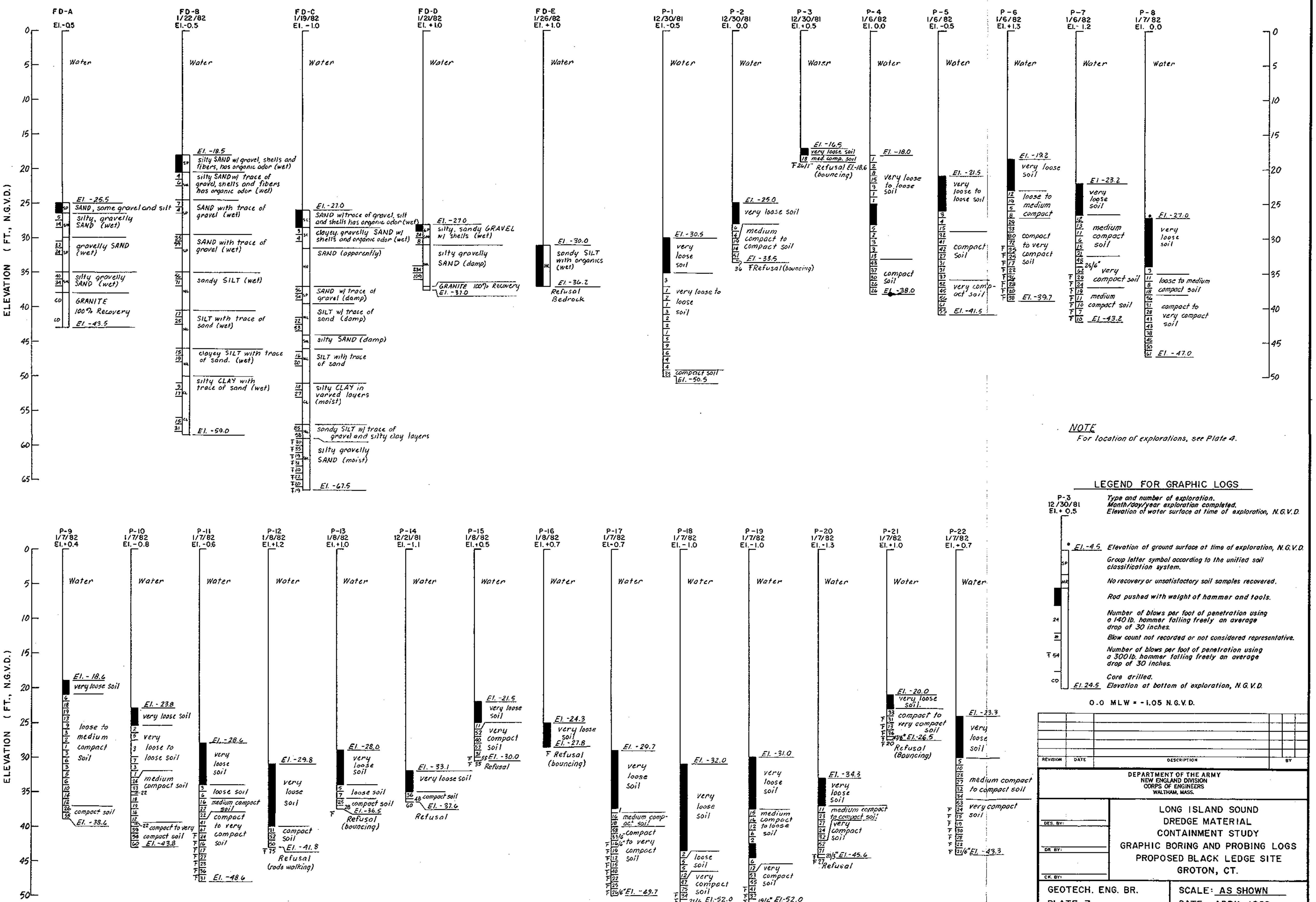
APPROVED CHIEF, ENGINEERING DIVISION DATE

SCALE SPEC. NO.

DRAWING NUMBER

SHEET

PLATE 6



NOTE
For location of explorations, see Plate 4.

LEGEND FOR GRAPHIC LOGS

P-3 12/30/81 El.+0.5 — Type and number of exploration. Month/day/year exploration completed. Elevation of water surface at time of exploration, N.G.V.D.

El.-4.5 — Elevation of ground surface at time of exploration, N.G.V.D.

SP — Group letter symbol according to the unified soil classification system.

NR — No recovery or unsatisfactory soil samples recovered.

Rod pushed with weight of hammer and tools.

24 — Number of blows per foot of penetration using a 140 lb. hammer falling freely an average drop of 30 inches.

Blow count not recorded or not considered representative.

F 54 — Number of blows per foot of penetration using a 300 lb. hammer falling freely an average drop of 30 inches.

CO — Core drilled.

El. 24.5 — Elevation at bottom of exploration, N.G.V.D.

0.0 MLW = -1.05 N.G.V.D.

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

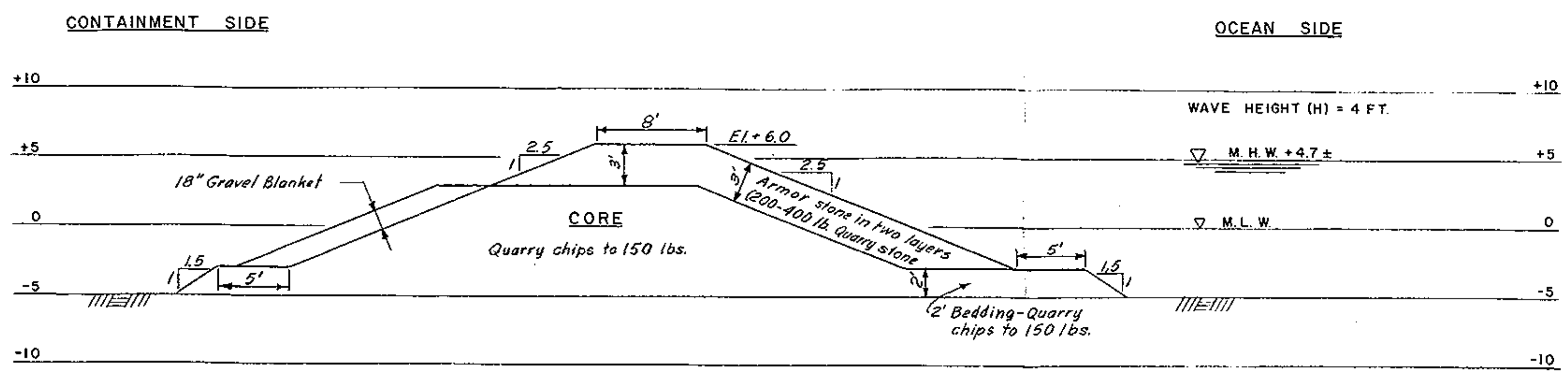
DES. BY:
DR. BY:
CK. BY:

LONG ISLAND SOUND
DREDGE MATERIAL
CONTAINMENT STUDY
GRAPHIC BORING AND PROBING LOGS
PROPOSED BLACK LEDGE SITE
GROTON, CT.

GEOTECH. ENG. BR.
PLATE 7

SCALE: AS SHOWN
DATE: APRIL 1982

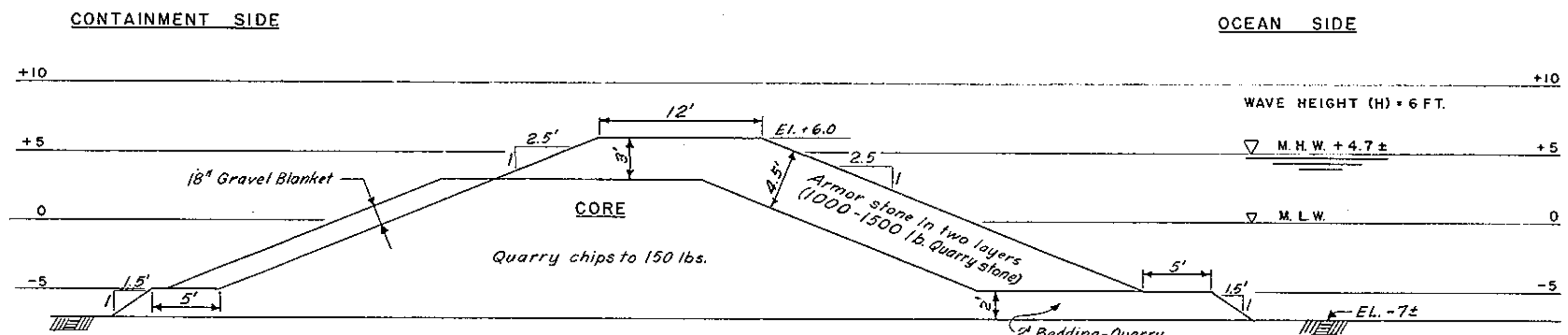
CORPS OF ENGINEERS U. S. ARMY



SECTION AT BORING FD-B

SCALE: 1" = 5'

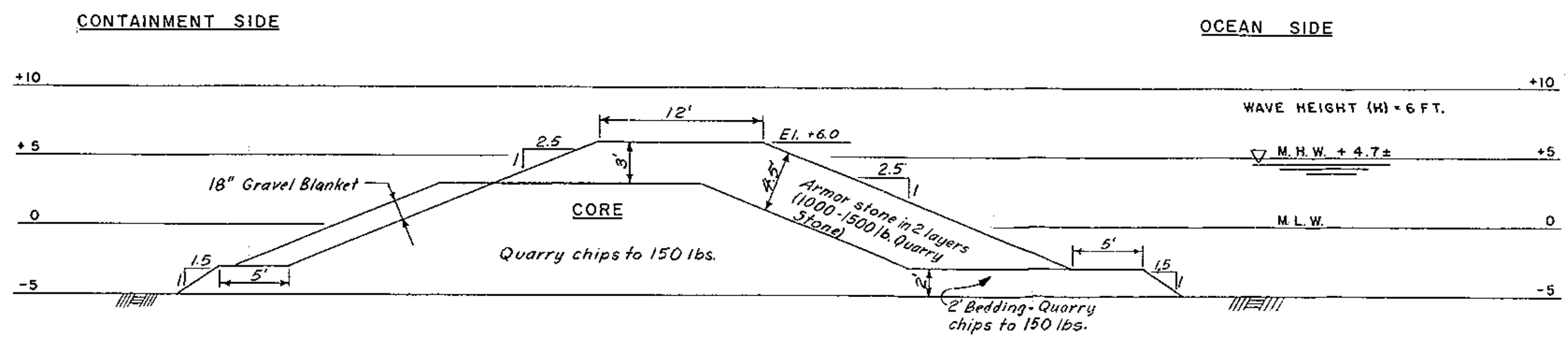
TYPICAL SECTION BORING FD-B TO NORTH SHORE (2000±FT.)



SECTION AT BORING FD-C

SCALE: 1" = 5'

TYPICAL SECTION PROBE P-11 TO BORING FD-B (1900±FT.)



SECTION AT PROBE P-11

SCALE: 1" = 5'

TYPICAL SECTION - WEST SHORE TO PROBE P-11 (1000± FT.)

NOTES

1. *For location of typical sections, see Plate 3.*
2. *Elevations are in feet and tenths and refer to Mean Low Water (M. L. W.)*
3. *0.0 M.L.W. = -1.95 National Geodetic Vertical Datum (N.G.V.D.)*

GRAPHIC SCALES

1" = 5' 0 5 10

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

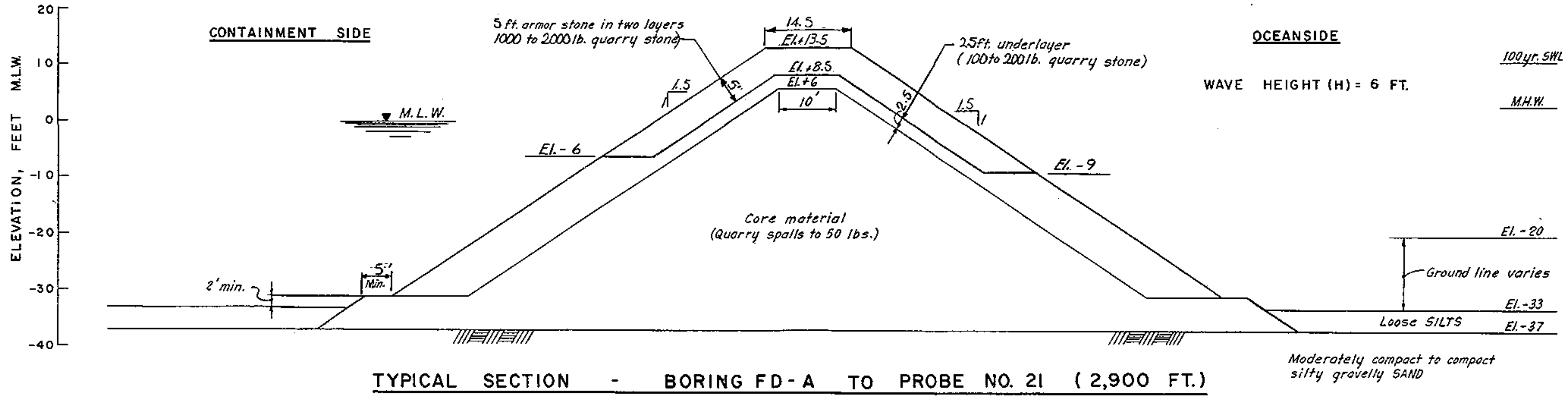
DES. BY:
DR. BY:
CK. BY:

LONG ISLAND SOUND
DREDGE MATERIAL
CONTAINMENT STUDY
TYPICAL CROSS SECTIONS
PROPOSED CLINTON HARBOR SITE
CLINTON, CT.

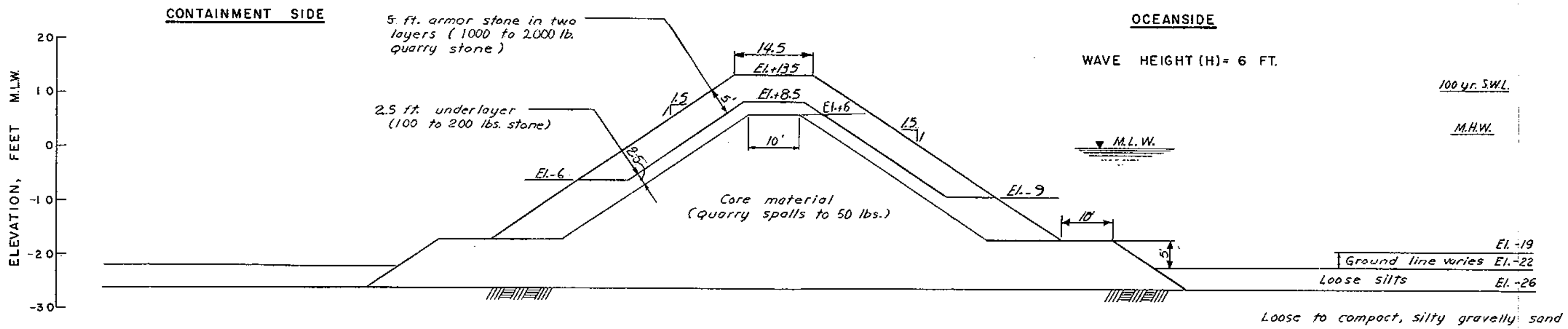
GEOTECH. ENG. BR.
PLATE 8

SCALE: AS SHOWN
DATE: APRIL 1982

CORPS OF ENGINEERS U. S. ARMY



TYPICAL SECTION - BORING FD-A TO PROBE NO. 21 (2,900 FT.)



TYPICAL SECTION - PROBE NO. 21 TO POINT "C" (1500 FT.)

NOTES

1. For locations of typical sections see Plate 4
2. Elevations are in feet and tenths and are referred to Mean Low Water (M. L. W.)
3. 0.0 Mean Low Water = -1.05 National Geodetic Vertical Datum (N.G.V.D)

GRAPHIC SCALES

1" = 10' 10 0 10 20

REVISION	DATE	DESCRIPTION	BY

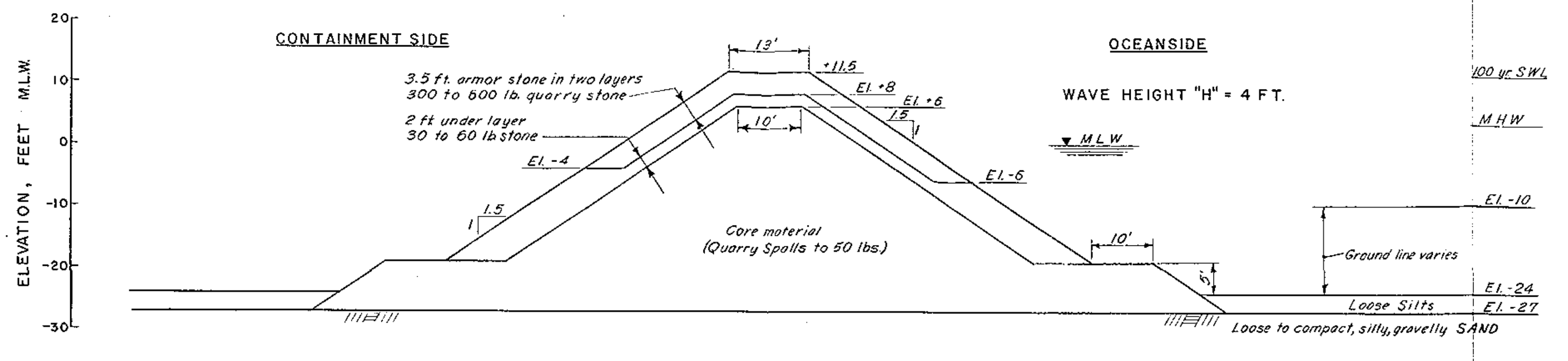
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY:
DR. BY:
CK. BY:

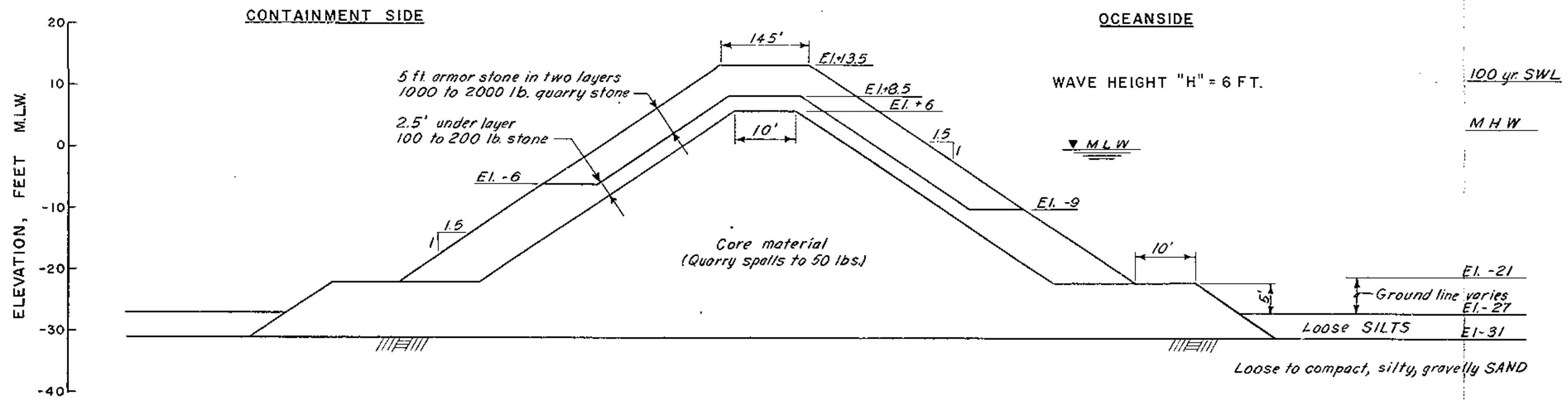
LONG ISLAND SOUND
DREDGE MATERIAL
CONTAINMENT STUDY
TYPICAL CROSS SECTIONS NO. 1
PROPOSED BLACK LEDGE SITE
GROTON, CT.

GEOTECH. ENG. BR.
PLATE 9

SCALE: AS SHOWN
DATE: APRIL 1982



TYPICAL SECTION - BORING FD-A TO POINT "B" (3200 FT)



TYPICAL SECTION - POINT "B" TO POINT "C" (1650 FT.)

NOTES

1. For location of Typical Sections see Plate 4
2. Elevations are in feet and tenths and are referred to Mean Low Water Datum (M.L.W.)
3. 0.0 M.L.W. = -1.05 National Geodetic Vertical Datum (NGVD)

GRAPHIC SCALES

1" = 10' 10 0 10 20

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES BY:
DR BY:
CK BY:

LONG ISLAND SOUND
DREDGE MATERIAL
CONTAINMENT STUDY
TYPICAL CROSS SECTIONS NO. 2
PROPOSED BLACK LEDGE SITE
GROTON, CT.

GEOTECH. ENG. BR.
PLATE 10

SCALE: AS SHOWN
DATE: APRIL 1982